LISA
System Design Overview

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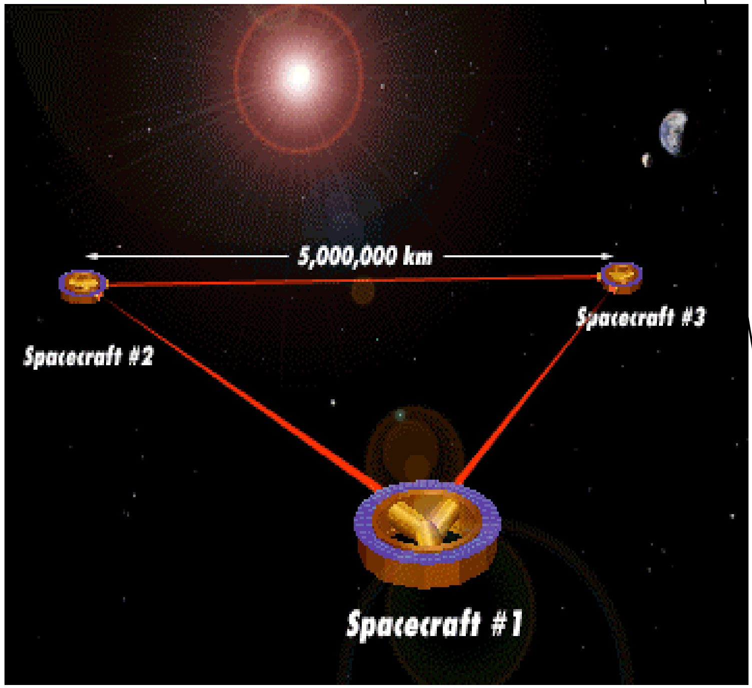
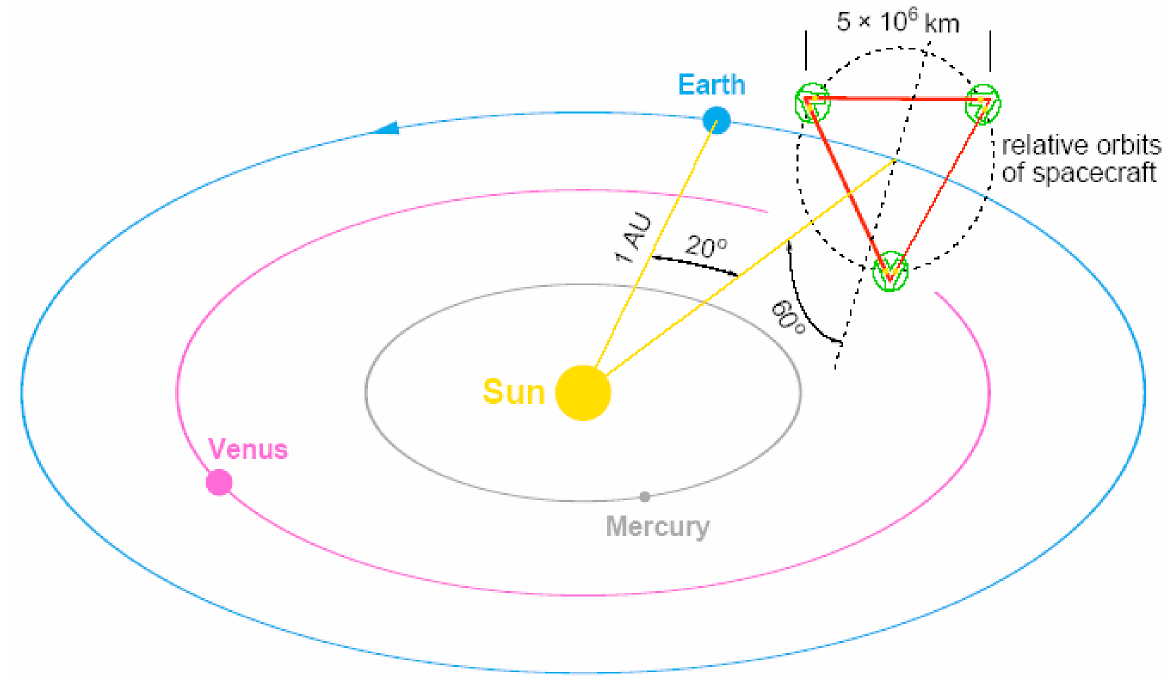
Overview

- Measurement Chain
- Performance
- Spacecraft Design Overview
- Payload Configuration
- Conclusions and Ongoing Work



The LISA Mission - Overview

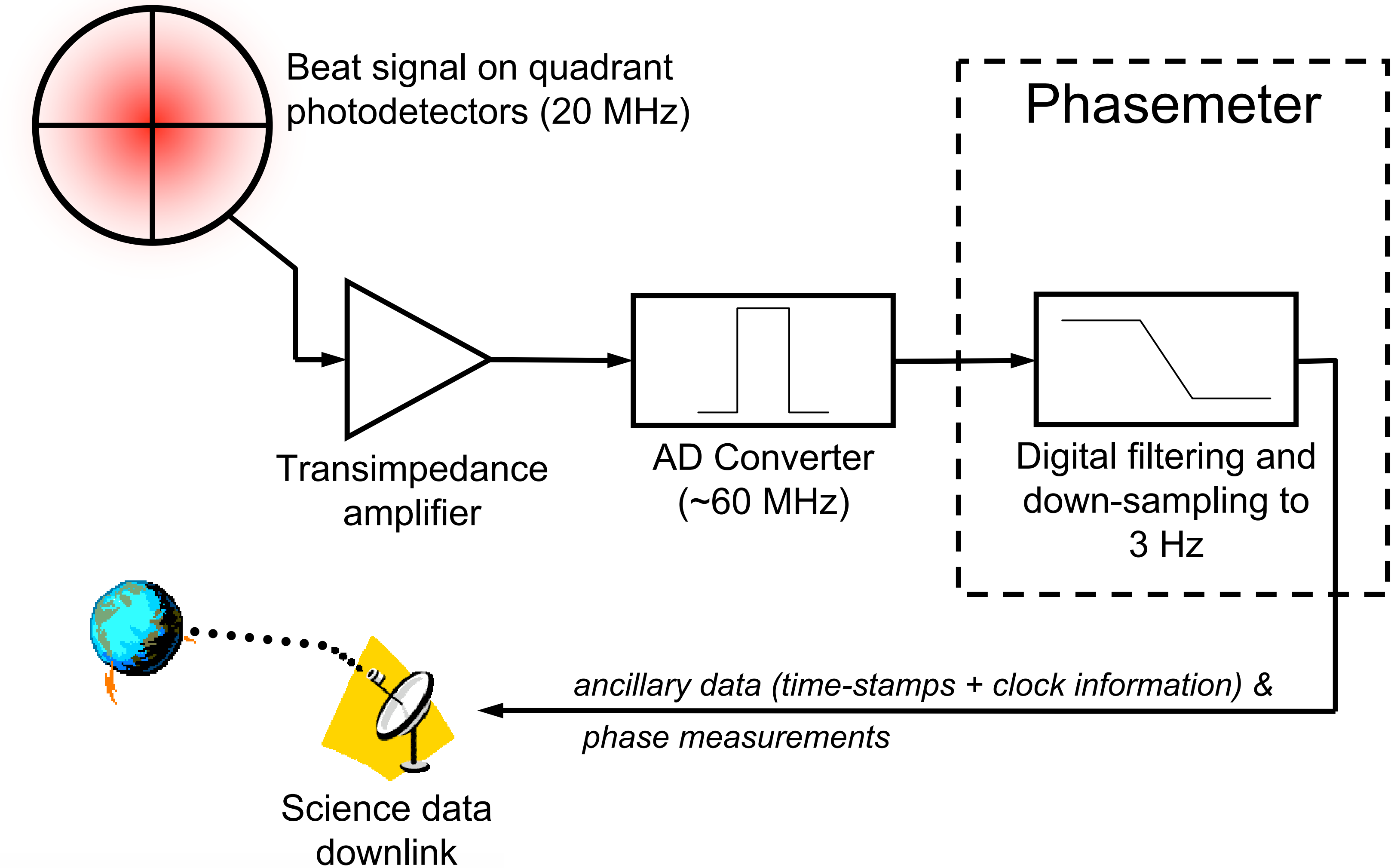
- Mission goal is to detect gravitational waves and characterize sources
- Measurement principle is laser interferometry with three spacecraft flying in a triangular constellation
- Interferometer arm-length: 5 mio km
- Measurement bandwidth: 0.1 mHz – 1 Hz



LISA Measurement Principle – Strap-Down

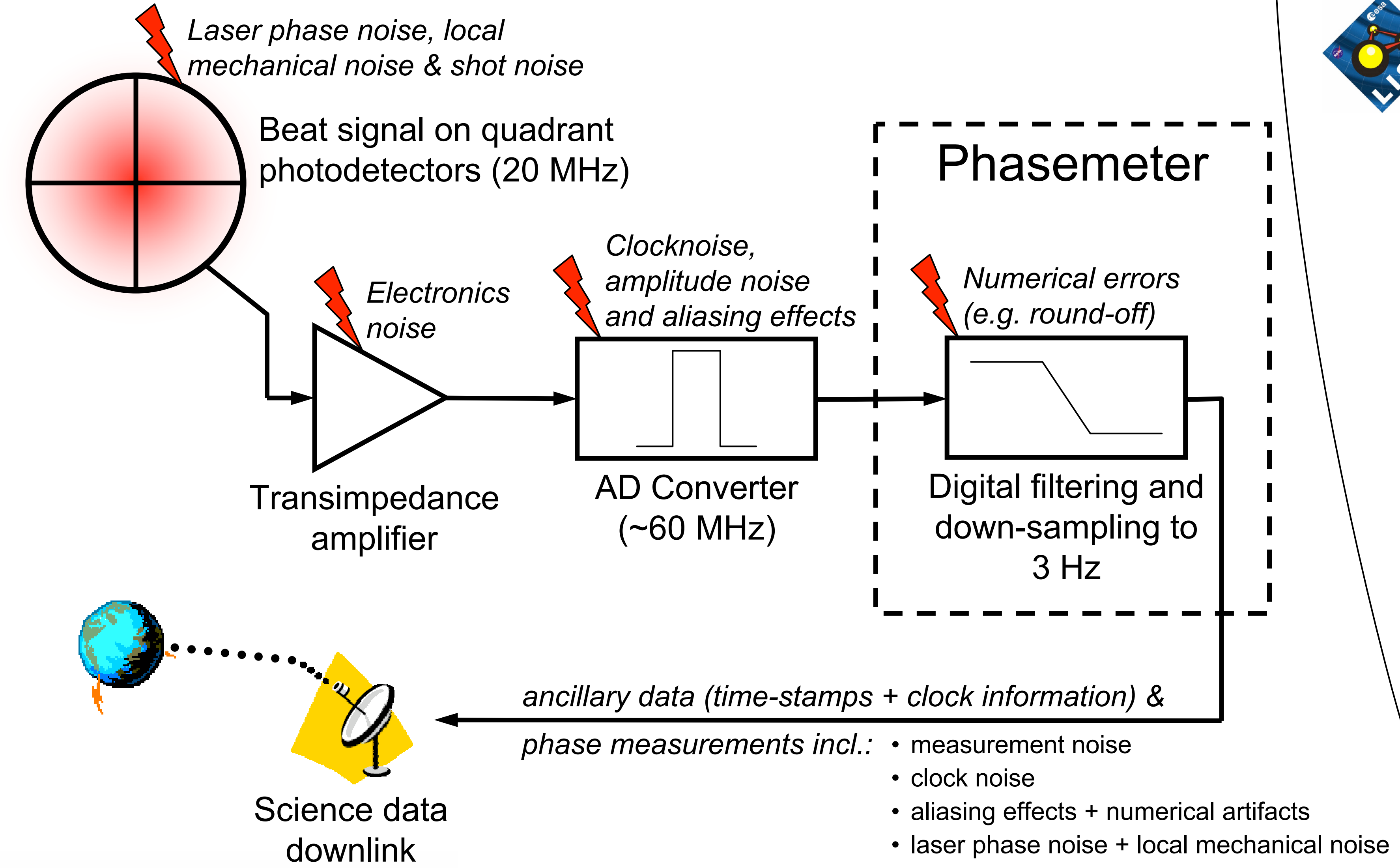
- **Laser interferometry between the spacecrafts**
  - beat-signals between different lasers are recorded on board of each spacecraft
  - during ground-processing, different interferometer setups can be synthetically generated with different sensitivities w.r.t. gravitational waves (time-delay interferometry; explained later)
- **Reference points are proof masses that define the inertial reference**
  - drag-free control isolates the proof masses from external disturbances (acceleration noise) in order to provide an inertial reference
- **Strap-Down system**
  - measurement from inertial sensor (IS) to IS is split into measurements from optical bench (OB) to IS and from OB to OB

LISA Measurement Chain
Onboard Data Acquisition

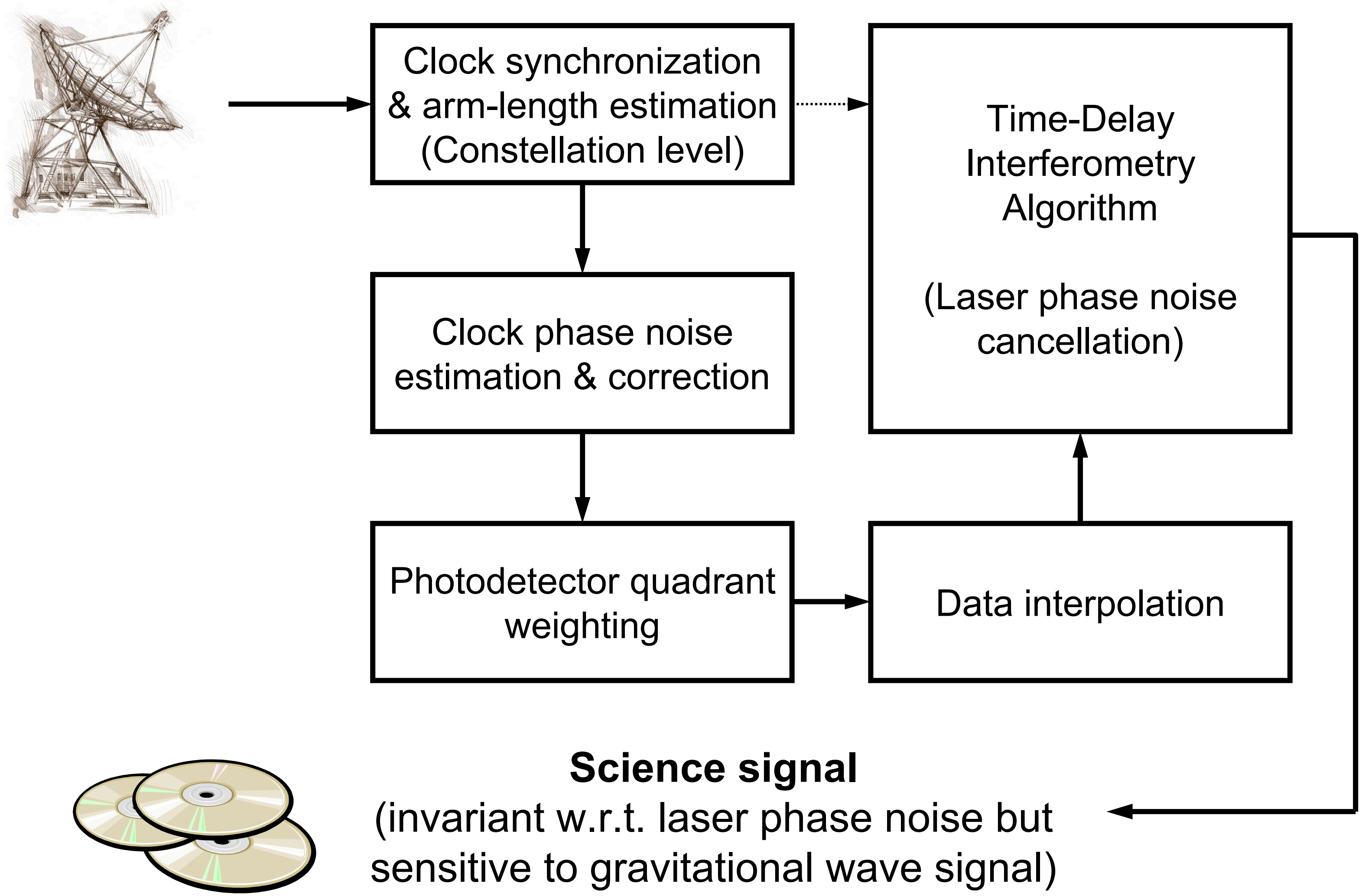


LISA Measurement Chain

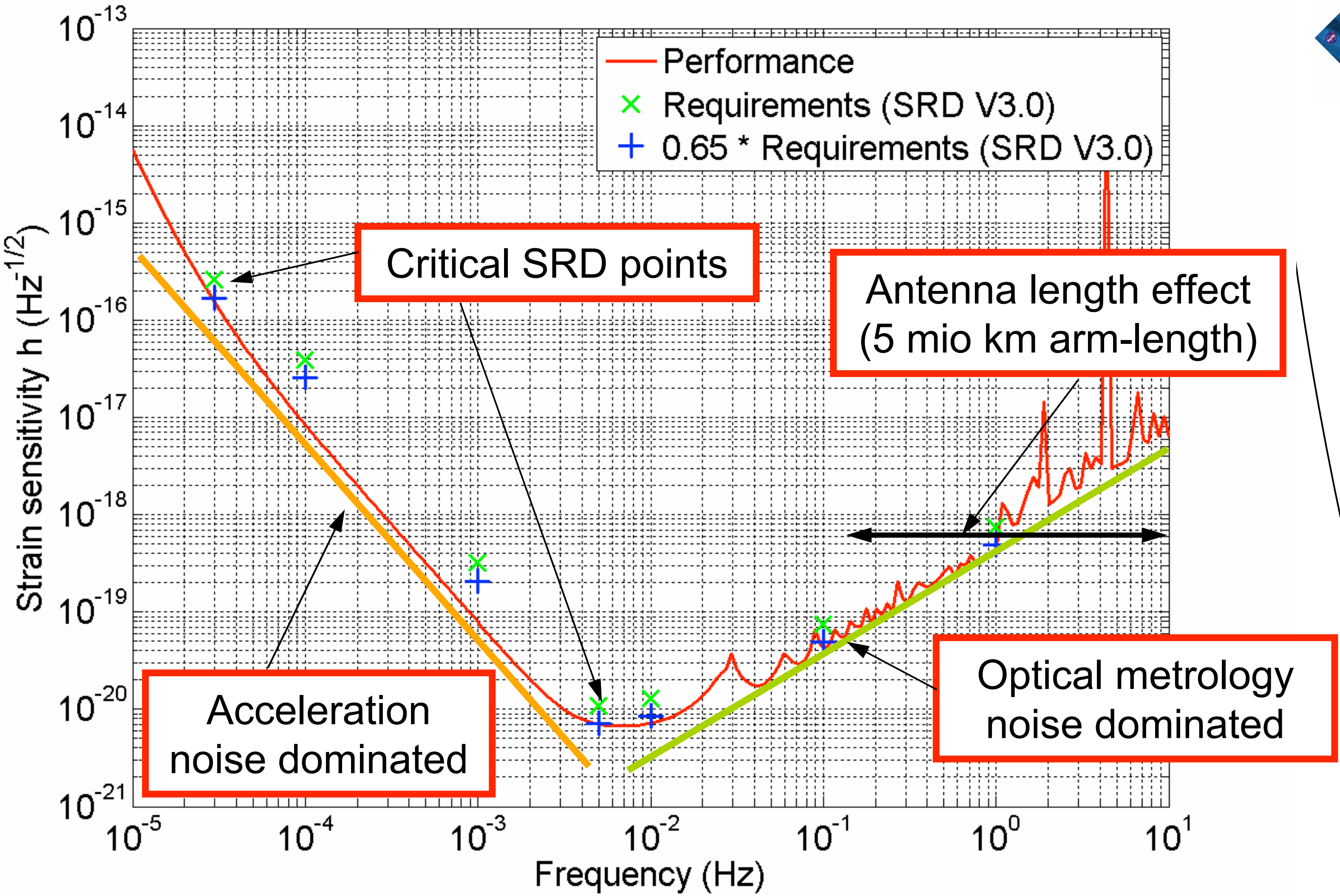
Onboard Data Acquisition



LISA Measurement Chain
On Ground Data Processing



Strain Sensitivity
Requirements & Performance



Requirement Breakdown

From Strain Sensitivity to Engineering Values

Strain Sensitivity

TDI transfer function

Measurement Sensitivity (Single Link)

Path Length Noise

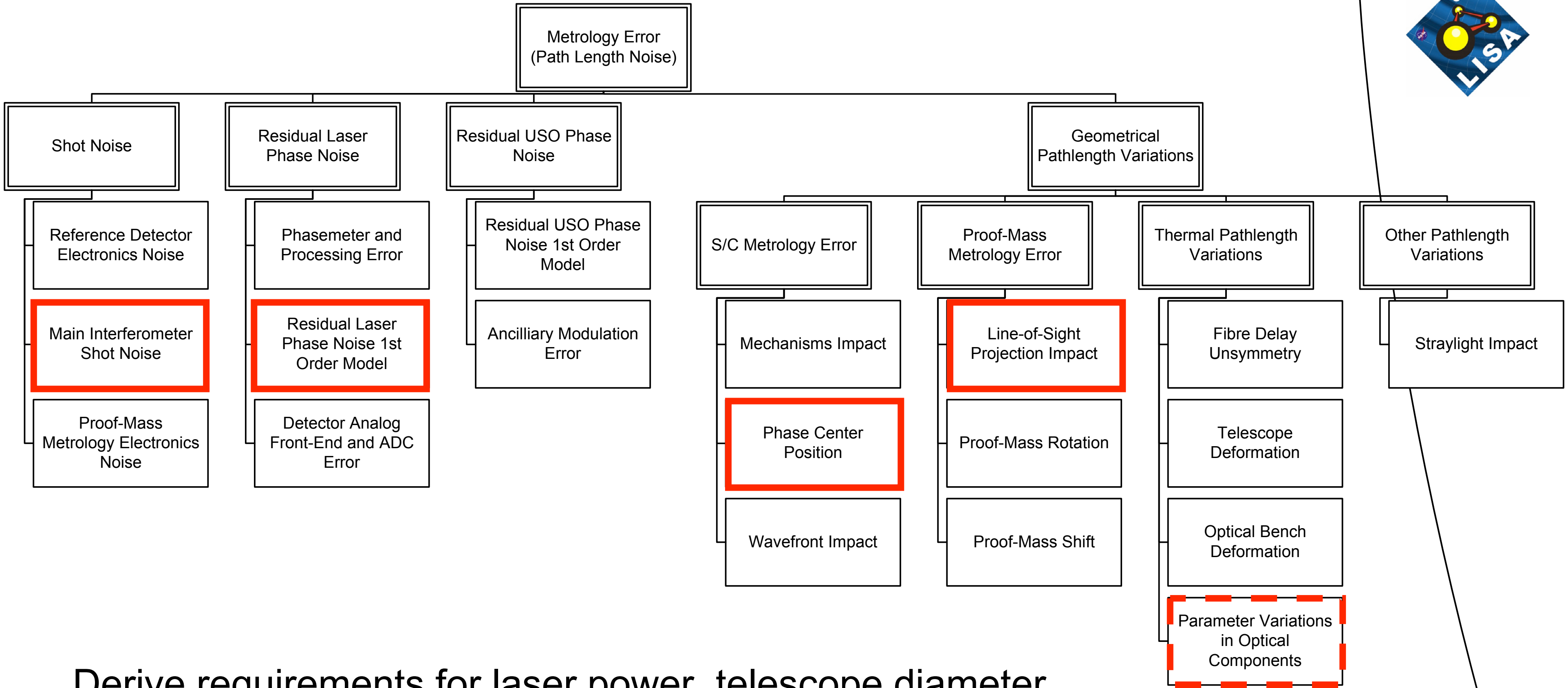
- Main influence above 1 mHz
- laser phase noise
- shot noise
- …

Acceleration Noise

- Main influence below 1 mHz
- magnetic fluctuations
- suspension actuation cross-talk
- …

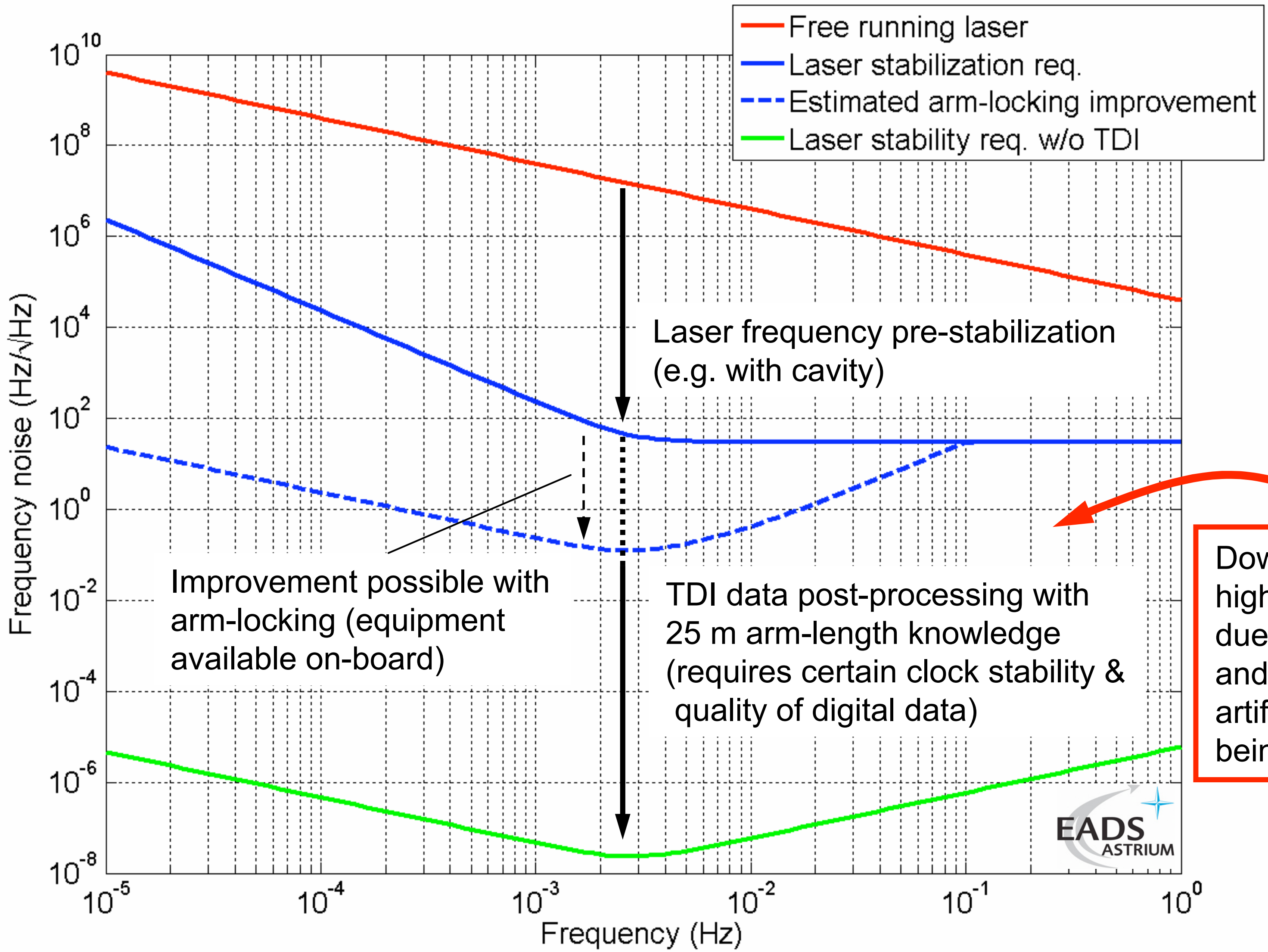
Metrology Error Breakdown

Derivation of Requirements for Optical Metrology



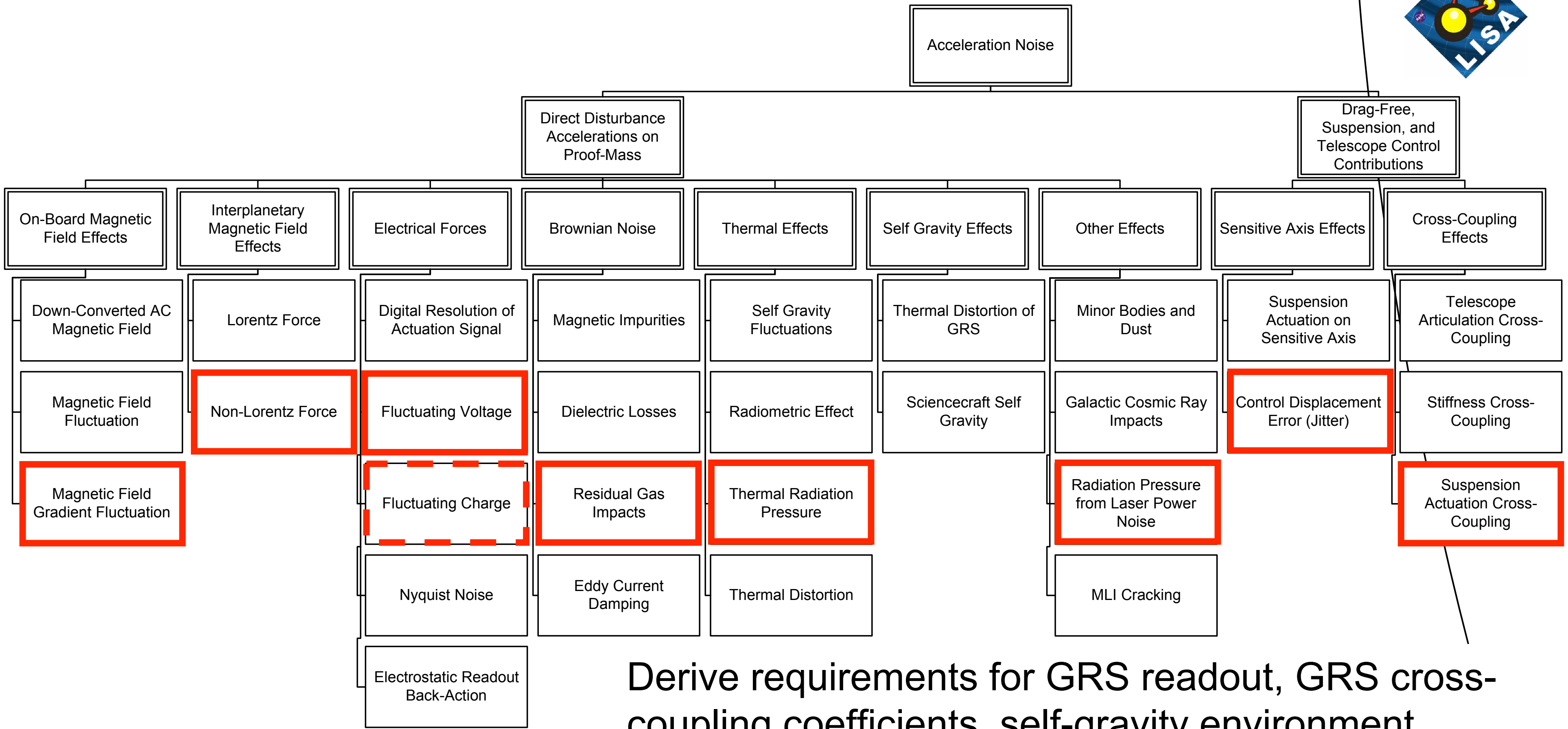
Derive requirements for laser power, telescope diameter, optical readout performance, mechanism noise, alignment errors, thermal stability, …

LISA Measurement - Laser Stability and TDI



Down conversion of high-frequency noise due to aliasing effects and numerical artifacts (currently being investigated)

Acceleration Noise Breakdown
Derivation of Requirements for GRS



Derive requirements for GRS readout, GRS cross-coupling coefficients, self-gravity environment, magnetic environment, voltage stability, charge environment, laser power stability, …

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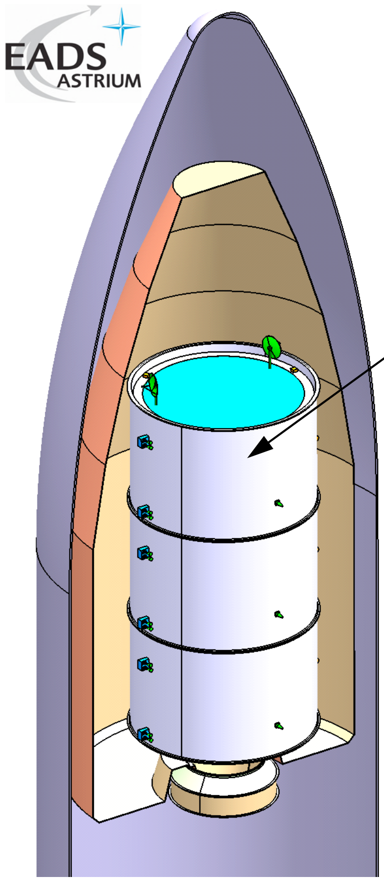
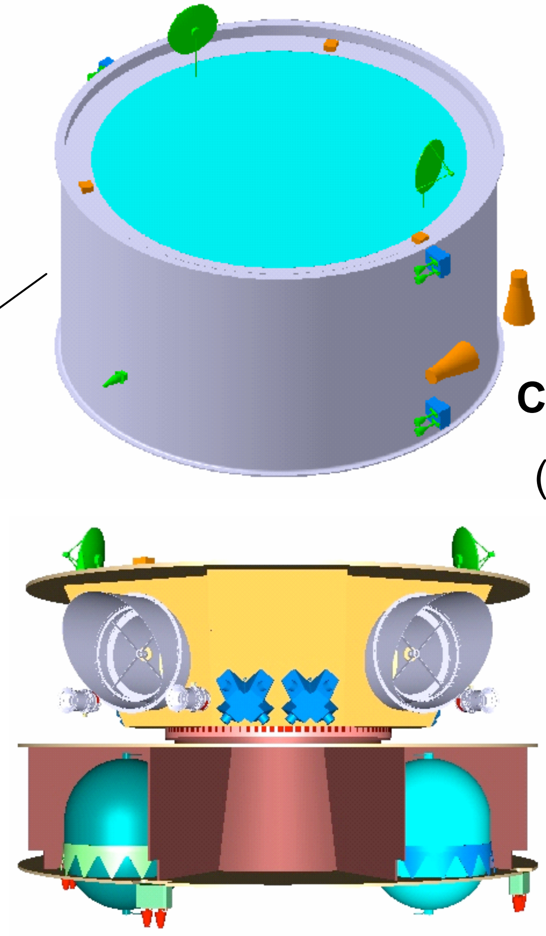
LISA System Architecture – Launch Stack



Launch Stack (Atlas 531)



Composite S/C

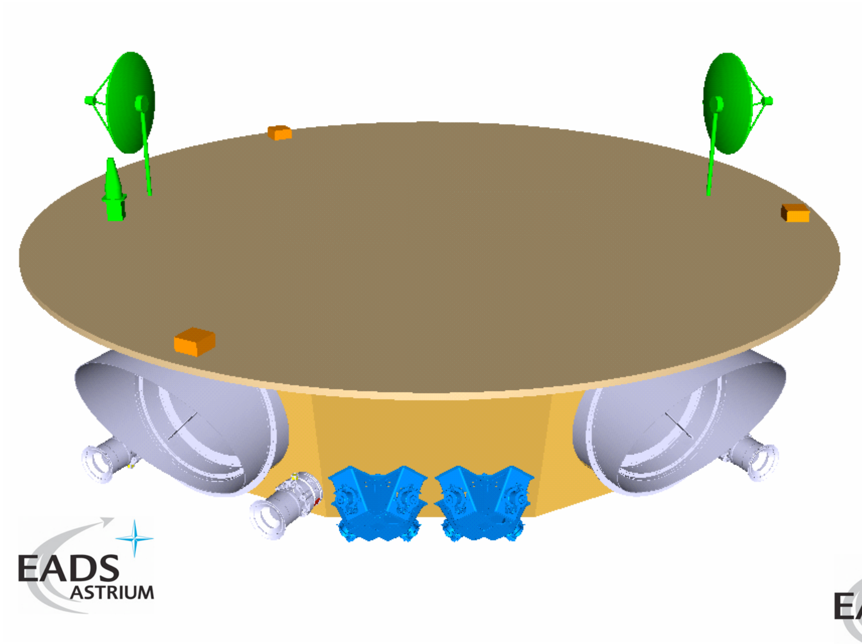
(Prop. Module
+
Sciencecraft)

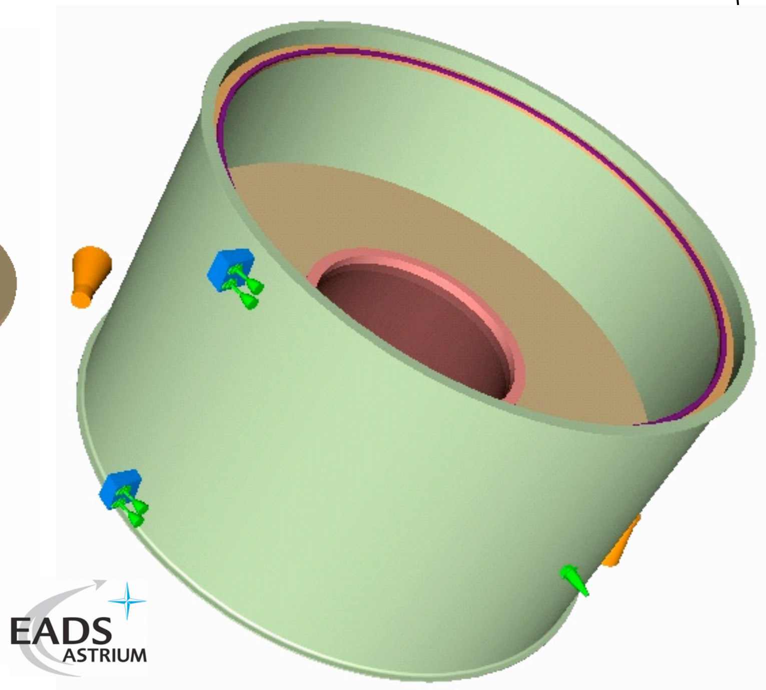
Launch stack mass (wet, launch date dependent):

worst case: 4643 kg

best case: 4510 kg

LISA Sciencecraft and Propulsion Module





Sciencecraft

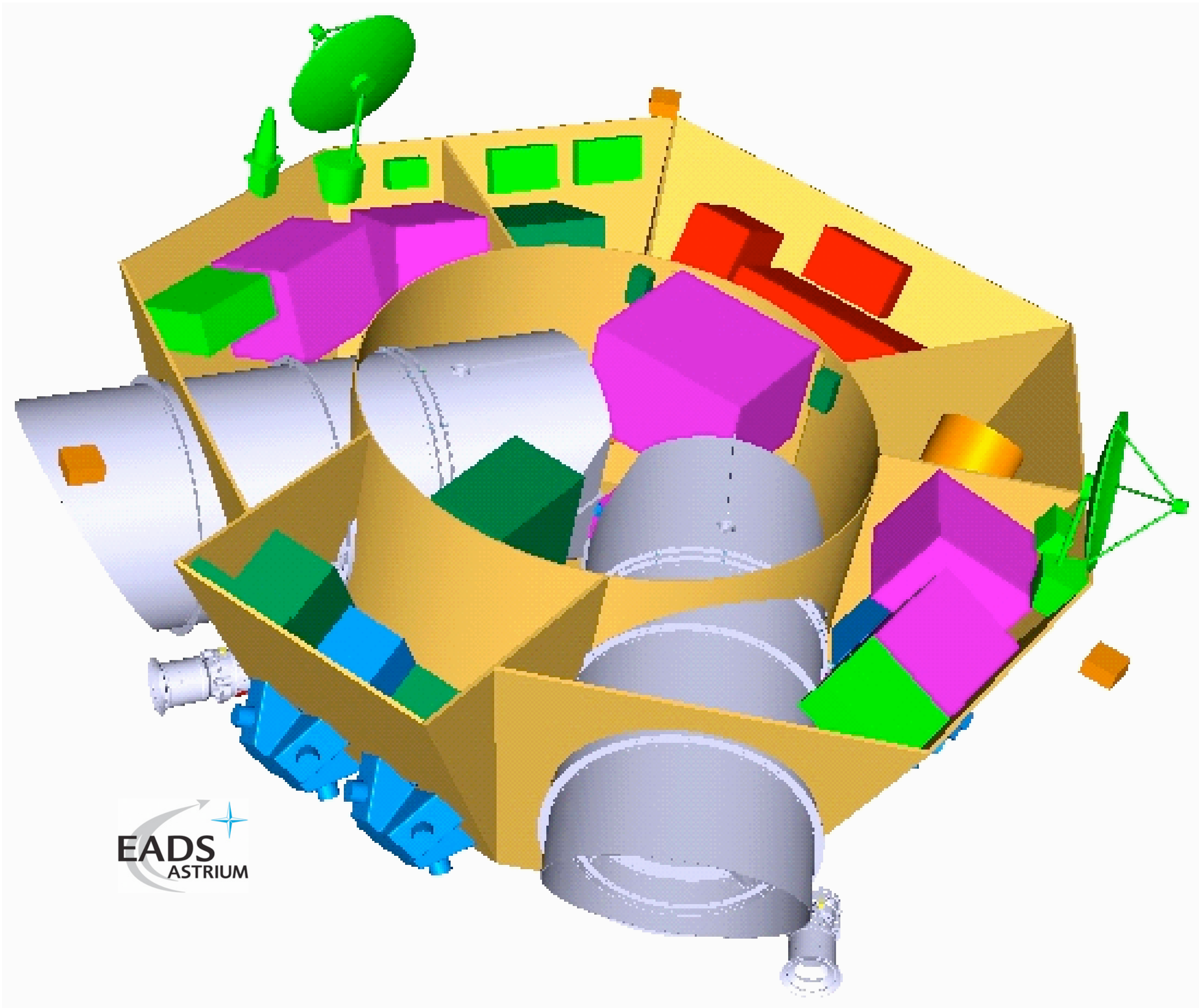
Sciencecraft mass: 524 kg (incl. payload)

Propulsion Module

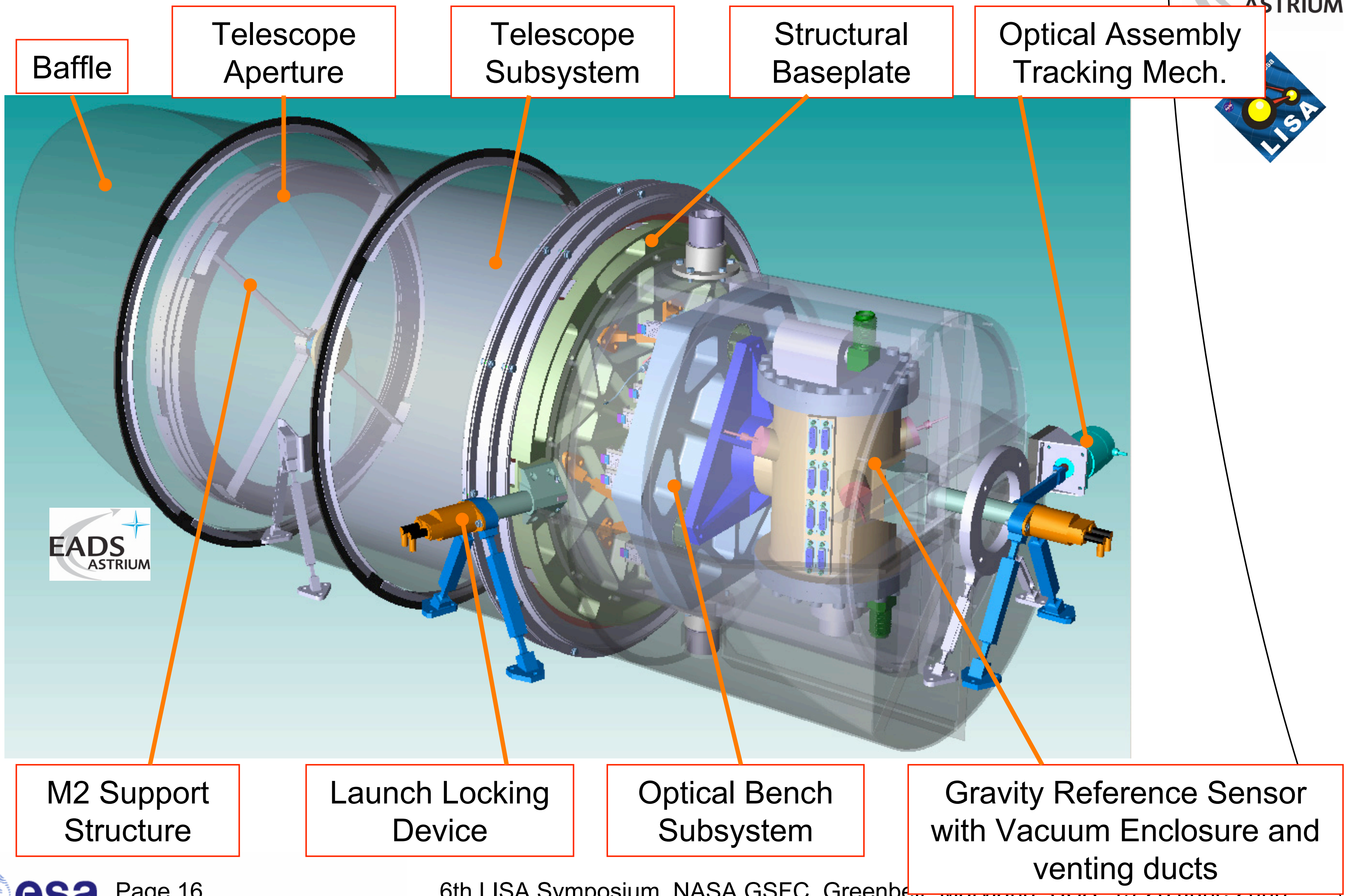
Propulsion module mass: 305 kg (dry)

Max. total ΔV: 1130 m/s

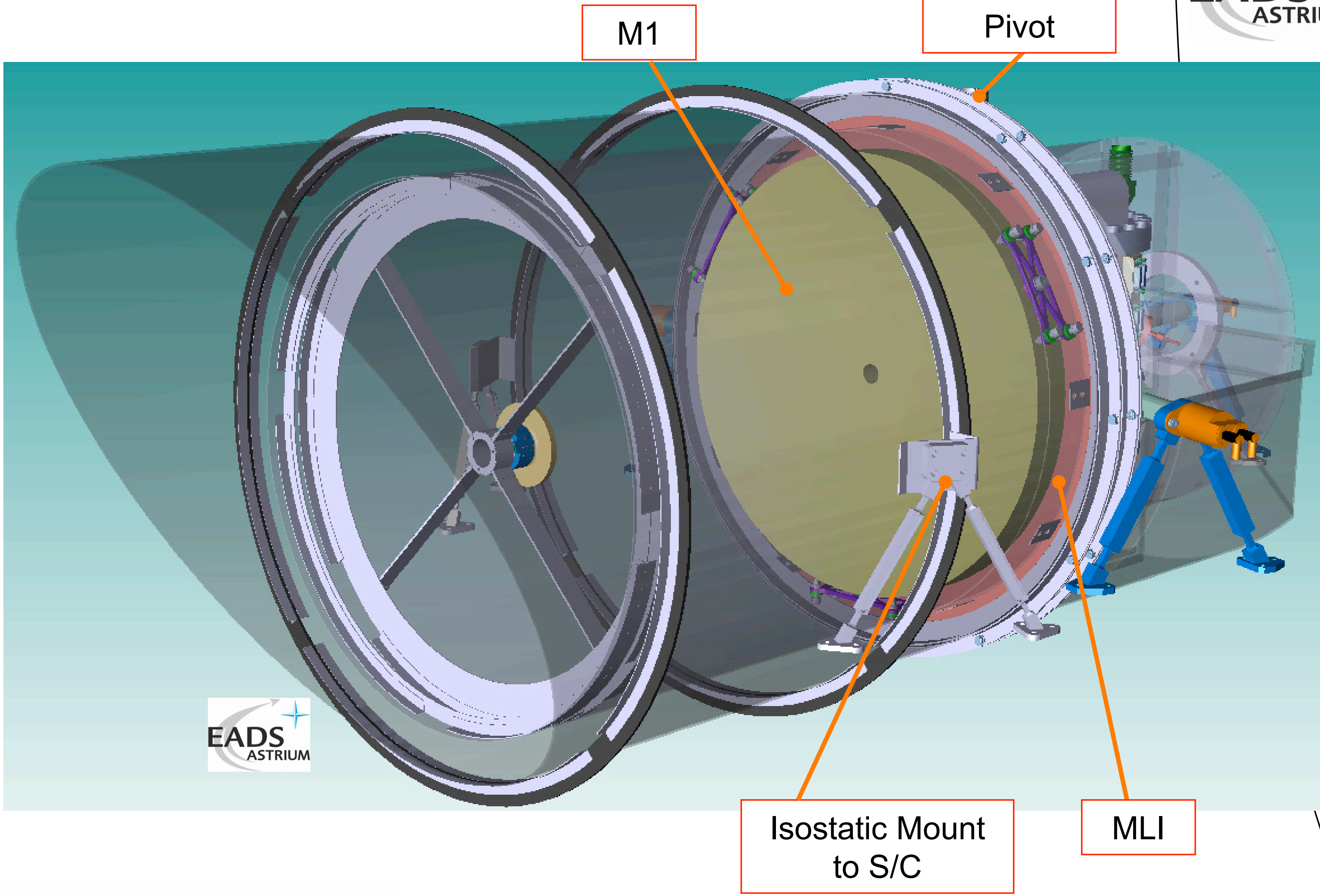
LISA Spacecraft - Unit Accommodation



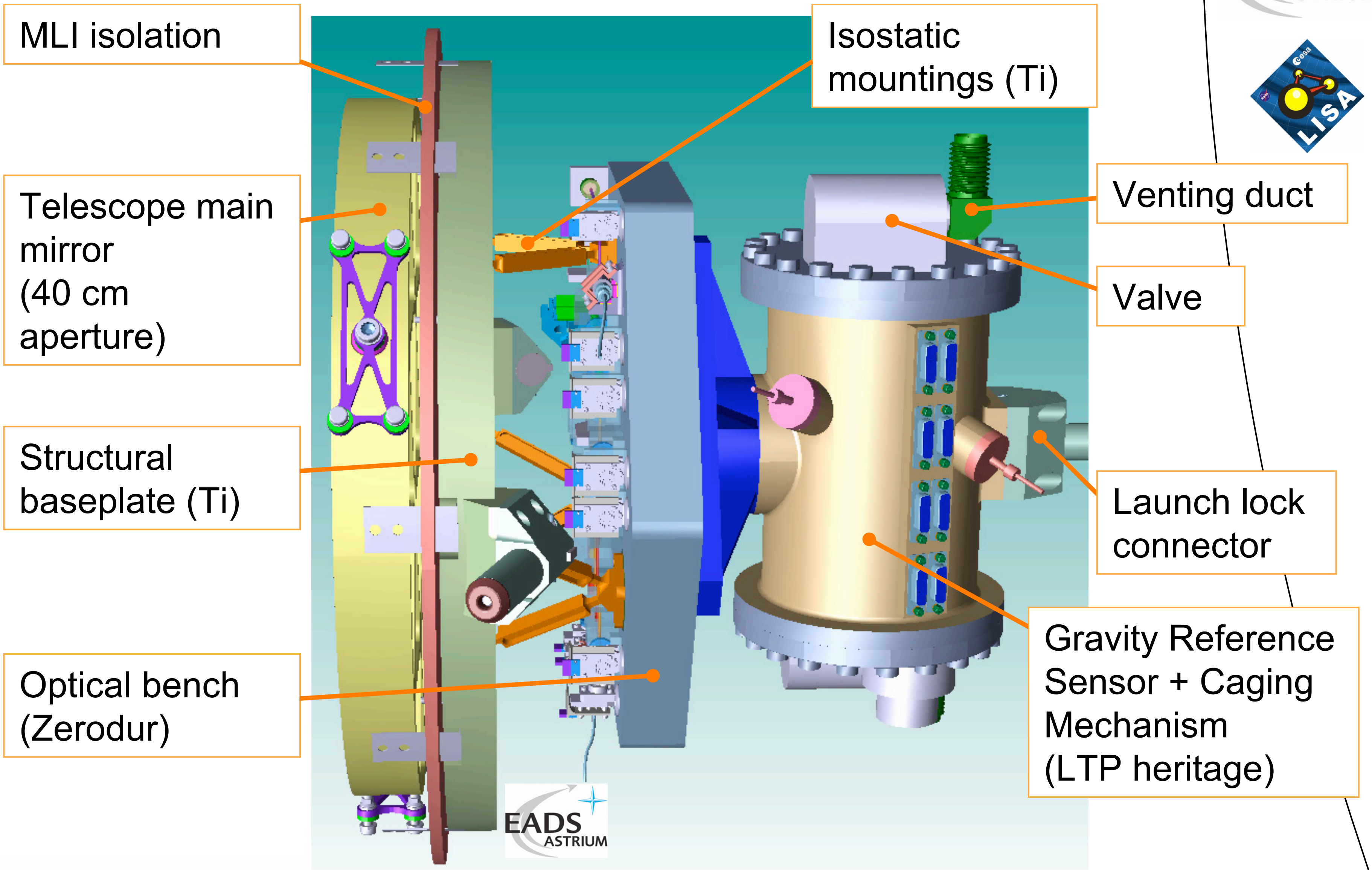
Payload – Current Design Status (1)



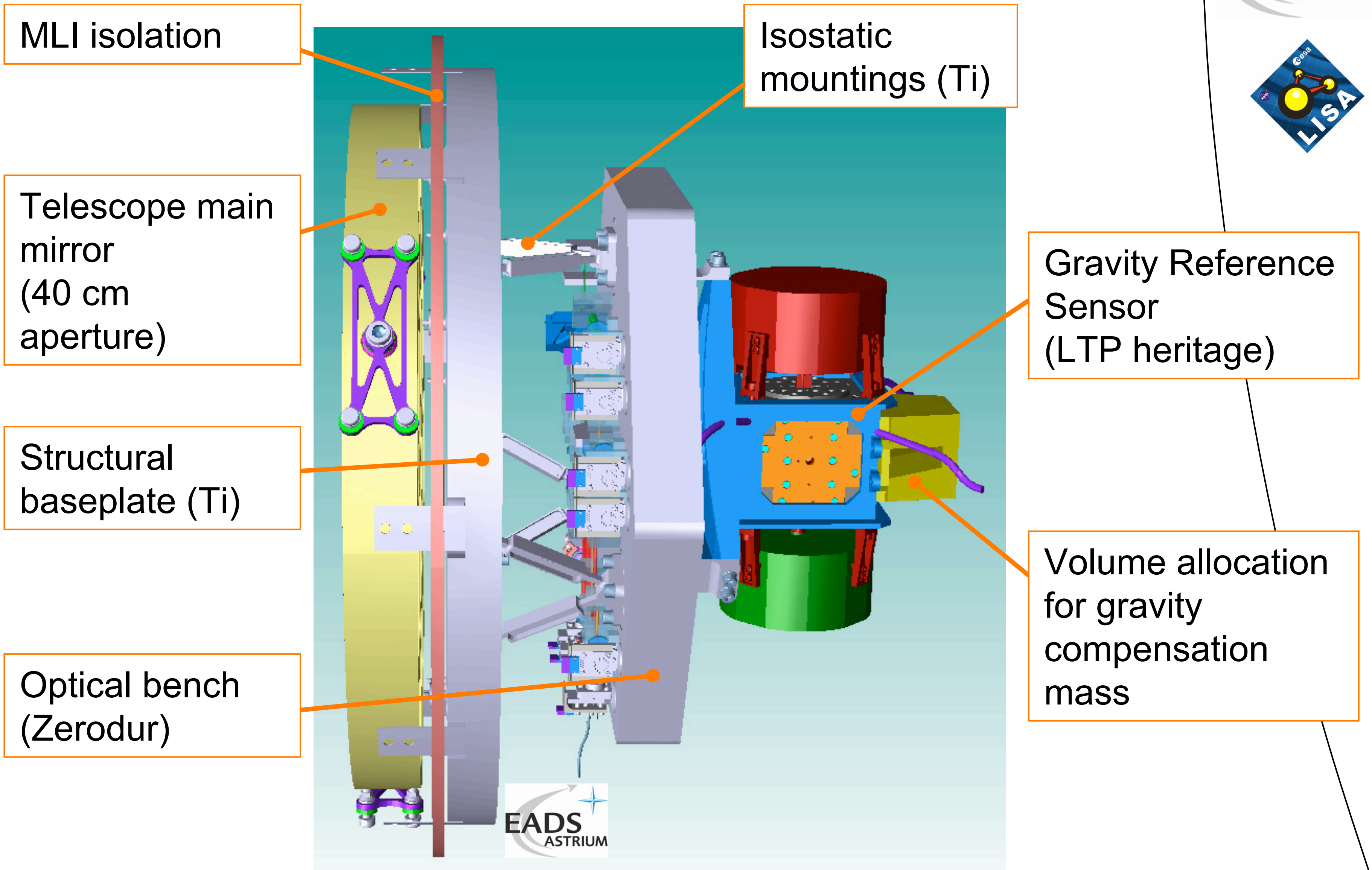
Payload – Current Design Status (2)



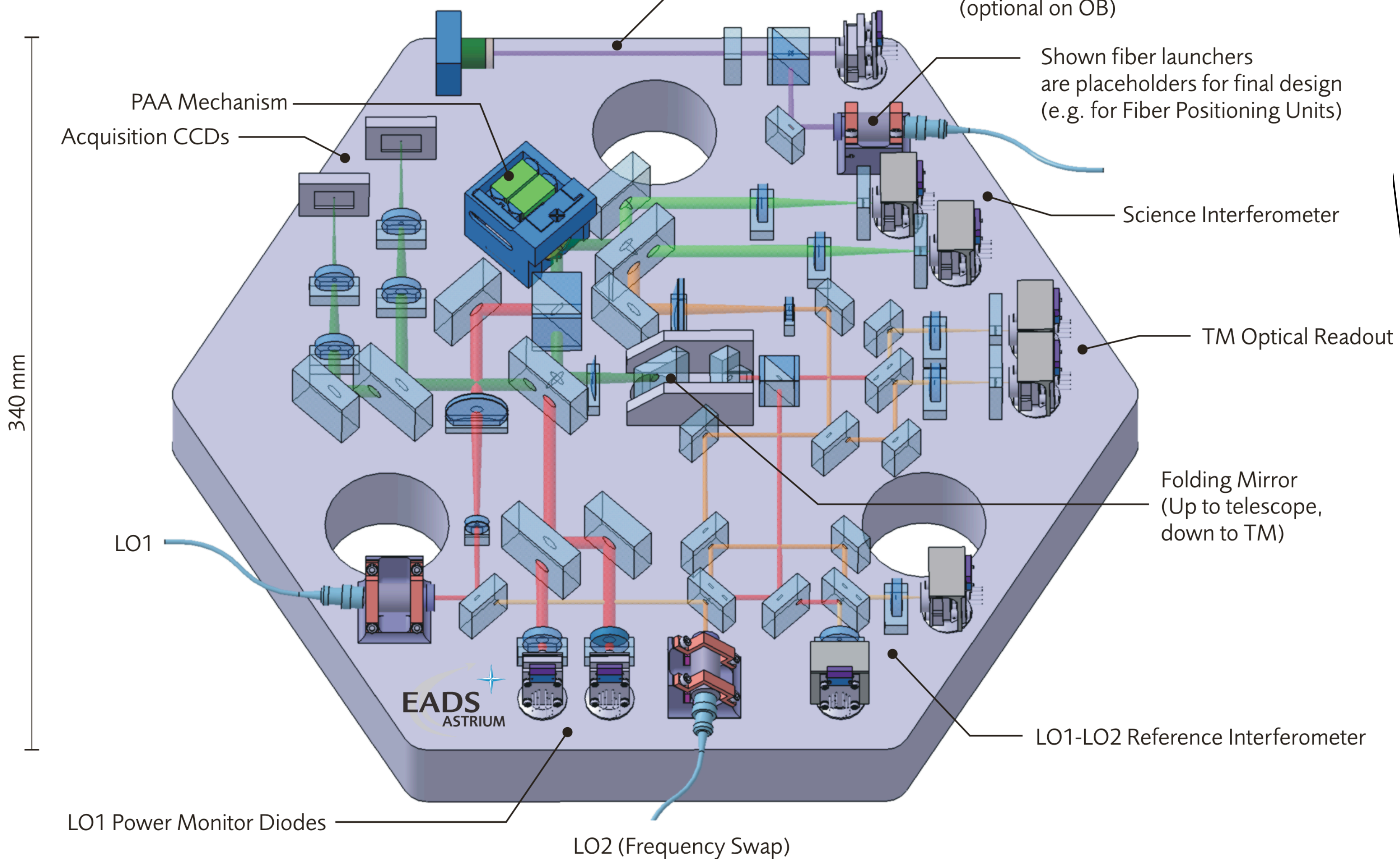
LISA Optical Assembly - Core Elements



LISA Optical Assembly – Open GRS Option

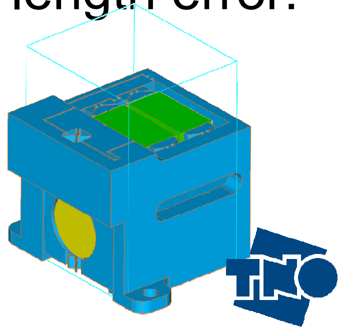


Optical Bench – Overview



PAA Mechanism – Piston Noise Breakdown

- Overall allocation for piston-induced path length error:
  - 3 pm/√Hz, $1/f^2$ roll-off below 2.8 mHz

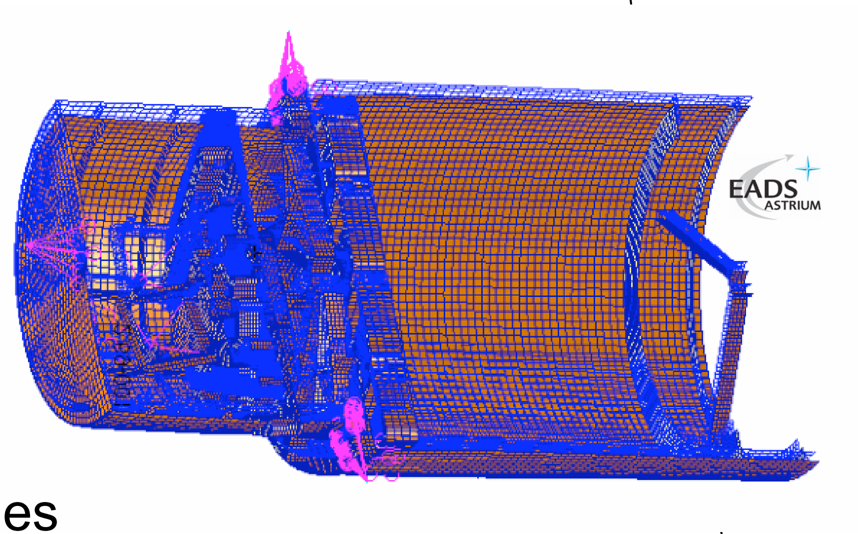


- Breakdown:

Error source	Symbol	Allocation
Distance of pivot axis from mirror surface	$\|\Delta x\|$	< 1 mm
Lateral misalignment of incident beam on mirror	$\|\Delta z\|$	< 50 μm
Mirror tilt jitter	$\|\delta\alpha\|$	$15\frac{\text{nrad}}{\sqrt{\text{Hz}}}\times\sqrt{1+\left(\frac{2.8\text{ mHz}}{f}\right)^4}$
Longitudinal mechanical jitter of pivot axis	$\|\delta\Delta x\|$, $\|\delta a\|$	$0.5\frac{\text{pm}}{\sqrt{\text{Hz}}}\times\sqrt{1+\left(\frac{2.8\text{ mHz}}{f}\right)^4}$
Lateral mechanical jitter of pivot axis	$\|\delta\Delta z\|$, $\|\delta b\|$	$0.5\frac{\text{nm}}{\sqrt{\text{Hz}}}\times\sqrt{1+\left(\frac{2.8\text{ mHz}}{f}\right)^4}$

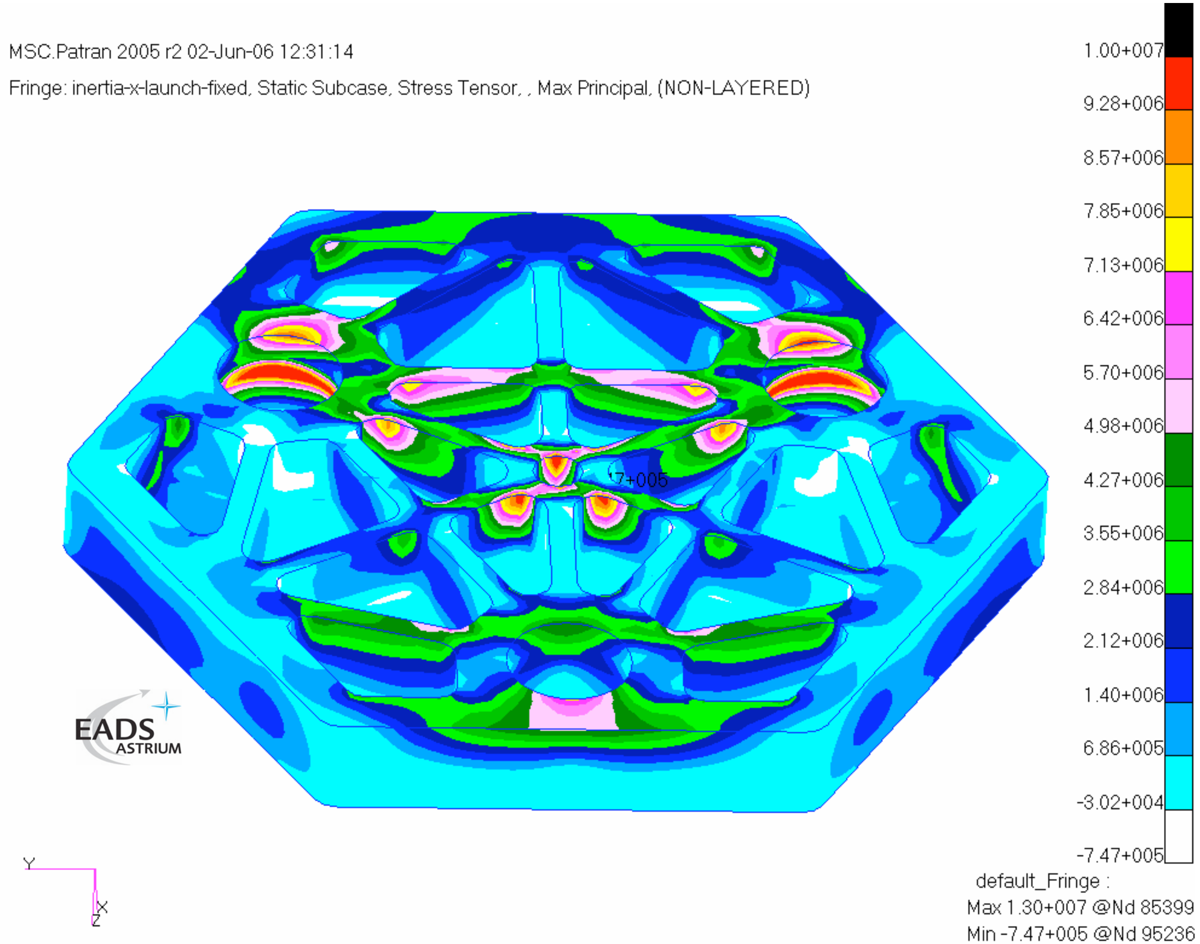
FEM Analysis - Eigenmodes

- Mode 1: 82.78 Hz
  GRS assembly swinging around z
- Mode 2: 83.01 Hz
  Structural baseplate oscillation in x
- Mode 3: 87.49 Hz
  GRS assembly swinging around y
- Mode 4: 128.47 Hz
  Spider with M2



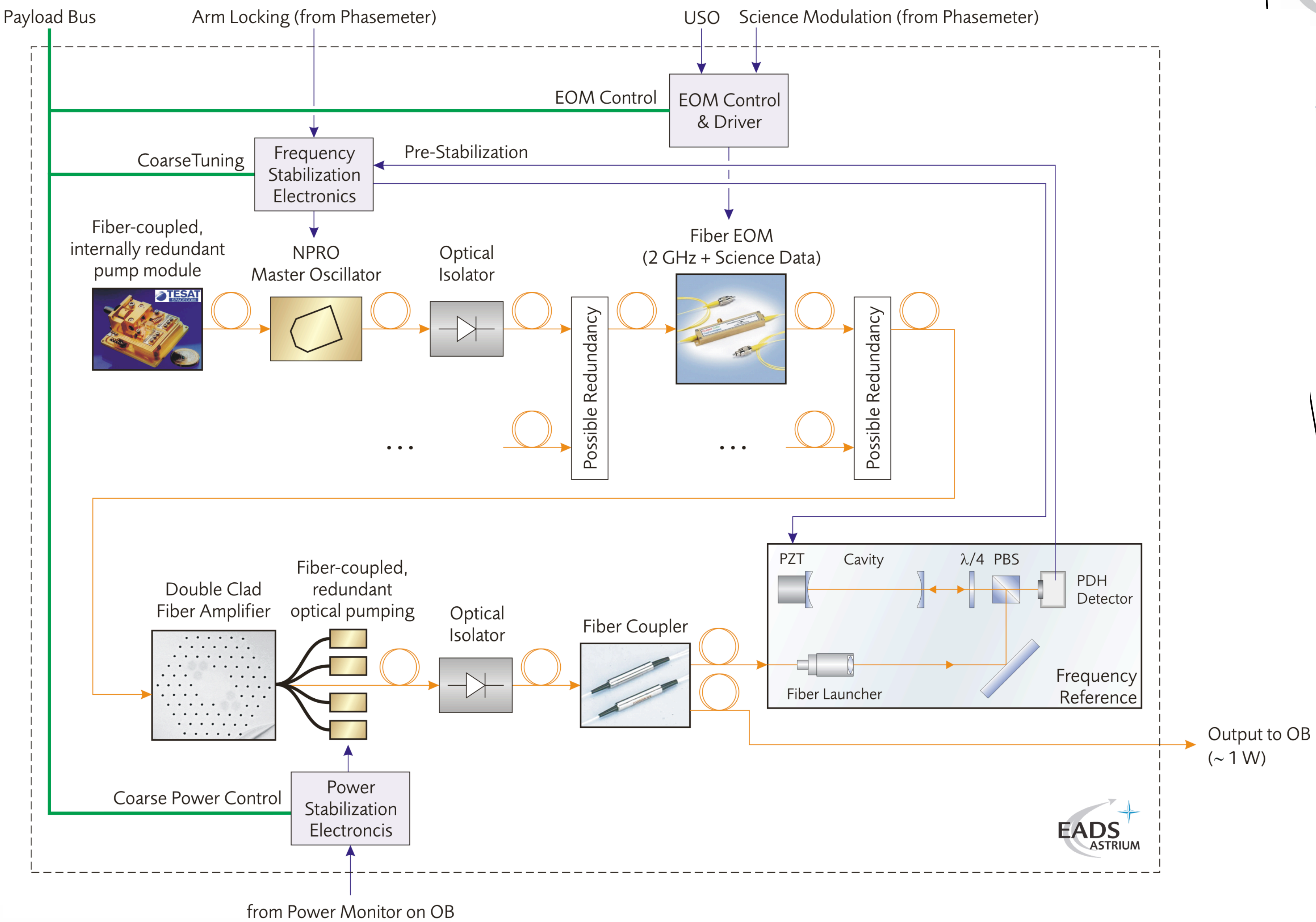
- All eigenmodes > 80 Hz
- Potential for slightly higher frequencies currently not used due to ongoing payload design update

FEM Analysis – Optical Bench Stress Analysis



Stress at inserts computed as < 3 MPa @ 30 g based on interface forces

Functional Architecture – Laser System Baseline



Conclusions and On-Going Work

- A feasible design baseline was established
- Critical points in the design are identified and technology programs will be initiated in order to verify the proposed baseline solutions
- Detailed requirement specifications for all subsystems will be developed until the end of the LISA Mission Formulation study

- Alternative LISA payload design is currently being investigated with the potential of further mass savings, simplification, risk reduction, and complexity reduction